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INVESTIGATION OF ICING CHARACTERISTICS OF TYPICAL LIGHT-AIRPLANE ENGINE INDUCTION SYSTEMS

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SUMMARY

The icing characteristics of two typical light-airplane engine induction systems were investigated using the carburetors and manifolds of engines in the horsepower ranges from 65 to 85 and 165 to 185. The smaller system consisted of a float-type carburetor with an unheated manifold and the larger system consisted of a single-barrel pressure-type carburetor with an oil-jacketed manifold.

Carburetor-air temperature and humidity limits of visible and serious icing were determined for various engine power conditions. Several methods of achieving ice-free induction systems are discussed along with estimates of surface heating requirements of the various induction-system components.

A study was also made of the icing characteristics of a typical light-airplane air scoop with an exposed filter and a modified system that provided a normal ram inlet with the filter located in a position to induce inertia separation of the free water from the charge air.

The principle of operation of float-type carburetors is proved to make them inherently more susceptible to icing at the throttle plate than pressure-type carburetors. The results indicated that proper jacketing and heating of all parts exposed to the fuel spray can satisfactorily reduce or eliminate icing in the float-type carburetor and the manifold. Pressure-type carburetors can be protected from serious icing by proper location of the fuel-discharge nozzle combined with suitable application of heat to critical parts.

INTRODUCTION

Increased use of small privately owned airplanes in recent years and the possibility of very widespread use in the future has made the safe operation of these airplanes in any atmospheric condition of

great importance. Safety in flight can be improved by reducing the number of items that require pilot attention and judgment, one of the most important considerations being the prevention of ice formation in the induction system. Most of the aircraft in the light-airplane class currently depend on pilot operation of a carburetor-heat control valve to prevent icing during flight at cruise power when the outside air temperature is below approximately 65° F and during glide-power operation at all air temperatures.

Icing characteristics of large engine induction systems used on commercial and military aircraft have been investigated (references 1 to 4) and modifications were suggested to the extent that trouble-free operation can be achieved under nearly all atmospheric conditions.

A broad investigation of the icing characteristics of various airplane induction systems was conducted at the NACA Lewis laboratory to determine the extent of induction-system icing in typical light airplanes, together with possible methods of reducing or eliminating icing by modification or improved design, and to establish a satisfactory safety guide for the use of anti-icing equipment.

A typical light-airplane induction system consists of a ram-air inlet, a filter, alternate exhaust-heated air supply, a float-type carburetor, and an unheated manifold connected by intake pipes to the cylinders. Some manufacturers supply pressure-type carburetors, oil-jacketed manifolds, or low-pressure fuel-injection systems on the larger engines and also on the smaller engines as optional equipment.

For simplicity, only the carburetors and the manifolds of the engines were used in the light-airplane engine carburetor-icing investigation reported herein and an exhauster system was employed to induce proper air flow and to provide necessary manifold-pressure conditions. Impact icing of light-airplane filters, which are usually mounted either flush with the front of the engine cowling or recessed a few inches into the inlet, was studied in the NACA Lewis icing research tunnel. A direct ram-air inlet with exposed filter is compared with a ram-air inlet that houses a submerged filter to induce inertia separation of water droplets from the carburetor air.

APPARATUS

A schematic diagram of the apparatus used to study carburetor-manifold icing (fig. 1), shows the air inlet, humidification system,

pressure-control valves, orifice, carburetor-manifold assembly, collector ring, and exhaust line. Air flow through the carburetor was induced by an exhauster system and was controlled by manually operated gate valves to simulate the air flow and the pressure values for the various engine operating conditions. Refrigerated air at -20° F was supplied to the system at very low relative humidity. Part of the incoming air was passed through an electric heater and, by means of thermostatically controlled dampers, heated and unheated air streams were blended to give temperature control at the carburetor. Steam was injected into the air for humidification. Temperature and humidity measurements were obtained with wet- and dry-bulb thermocouples installed in a plenum chamber at the carburetor inlet.

The induction systems investigated consisted of a float-type carburetor and manifold (fig. 2) for engines of 65 to 85 horsepower and a single-barrel pressure-type carburetor with a jacketed manifold (fig. 3) for engines of 165 to 185 horsepower. Data were obtained for the pressure-type carburetor with and without oil heating in the jacket.

The float-type carburetor and the manifold were modified for part of the investigation to allow circulation of a heated fluid through the throttle plate, the throttle body, and around the manifold. A hollow throttle plate was designed and constructed with provision for inlet and outlet connections at the ends of the throttle shaft. An annular passage was provided around the throttle body and the manifold was completely enclosed in an insulated metal box.

On an engine using a pressure-type carburetor, the oil-jacketed manifold system is bolted to the crankcase and has scavenge-oil inlets at the front and the rear with an outlet to the oil tank at the rear. As shown in figure 3, the manifold riser from the carburetor and the six outlets to the cylinders pass through the oil jacket. The top of the manifold is unheated, except for conduction from the jacketed part. In the laboratory investigation, the oil-jacketed manifold system consisted of a tank, a pump, a steam-to-oil heat exchanger, temperature- and flow-measurement equipment, and the jacketed manifold. Interior observation of the carburetor and the manifold was provided by a window in the bottom of the plenum chamber below the carburetor, a transparent plastic tube between the carburetor and the manifold, a window in the collector ring assembly, and glass extension tubes from the manifold outlets to the collector ring. (See fig. 1.) The fuel temperature was regulated to simulate flight conditions by means of a simple heat exchanger.

The filter and air-scoop impact-icing study was made in the test section of the icing research tunnel. Filters and air scoops were

installed on a flat plate inclined to the air stream in the tunnel test section. An outlet from the plenum chamber behind the filter extended outside the tunnel to an orifice and a blower, as shown in figure 4. A standard air scoop and filter of the type used with a fuel-injection system that does not require an alternate heated-air supply was first investigated. The chamber behind the filter is fitted with a spring-loaded damper to allow air induction from the engine compartment when the filter becomes blocked. An air scoop with a sheltered filter was designed in which the standard filter was so mounted that it induced water-inertia separation by turning the inlet-air stream approximately 120° before the air entered the filter. The standard and modified configurations are shown in figure 4. 1037

CONDITIONS AND PROCEDURE

The conditions selected for the carburetor investigation included glide, low-cruise, and high-cruise power ratings only at sea-level altitude. Because an increase in power or altitude for unsupercharged engines requires a greater throttle angle and a consequent reduction in severity of icing, the results at sea level are considered conservative (reference 1). Appropriate air flows and manifold pressures for the carburetors at the power conditions used were maintained for each part of the investigation.

In previous induction-system icing investigations (references 1, 3, and 4), visible icing and drop in air flow caused by ice blockage were used as parameters of the effect of icing on performance. The same parameters have been used for the investigation reported herein. Inspection of the carburetor and the manifold for traces of ice determined the limits of visible icing and a drop in air flow of 2 percent in 15 minutes was used as the criterion for serious icing. Any icing around the idle fuel-discharge holes of the float-type carburetor at glide power was designated serious because of the possibility that ice would form over the fuel outlets. Photographs of typical carburetor icing are shown in references 1 and 4.

Carburetor-air temperature and humidity ratio (as determined from wet- and dry-bulb temperature measurements) were varied to determine the limits of visible and serious icing at simulated glide, low-cruise, and high-cruise power conditions. Humidity ratios ranged from approximately 0.001 to 0.030 pound of water per pound of dry air for carburetor-air-inlet temperatures from 15° to 95° F.

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The decrease in air flow for an engine with ice forming in the carburetor is caused by the restriction due to the ice and the decreased demand by the engine due to speed reduction. In order to simulate the drop in air flow caused by icing of the carburetor, the pressure downstream of the manifold pressure-control valve was maintained below the critical pressure to make air flow through the valve proportional to the manifold pressure. The manifold pressure-control valve was heated to prevent ice blocking and subsequent air-flow loss at that point.

The modified float-type carburetor and manifold was heated by water at flow rates from 2 to 4 gallons per hour and temperatures from 45° to 150° F. The water was passed through the throttle plate, the throttle body, and the manifold in that sequence.

Heated oil was supplied to the oil-jacketed manifold of the pressure-type-carburetor system at a flow rate of 1 gallon per minute and a temperature of 170° F. The permissible engine-oil temperatures for most light airplanes are from 120° to 220° F. The temperature and the flow rate selected were approximate values characteristic of flight.

The temperature of the fuel entering the carburetor after passing through the heat exchanger was no more than 10° F above the carburetor-air temperature. With the storage capacity for fuel in the float chamber or diaphragm chamber of the carburetors, the fuel was somewhat further normalized to carburetor-air temperature. Reference 1 indicates that fuel temperature has much less effect on icing than the latent heat of vaporization of the fuel. More accurate control of the fuel temperature was therefore considered unnecessary. One trial was made with fuel and carburetor-air temperatures of 15° and 60° F, respectively, however, to determine whether very cold fuel entering the carburetor would cause condensation of moisture on the tube leading to the discharge nozzle and subsequent icing at that point. The difference caused by the use of cold fuel was undetectable.

In order to determine the effect of impact icing on air scoops and filters, the following conditions were maintained in the icing research tunnel: airspeed, 80 miles per hour; air-temperature range, 17° to 22° F; air flow through the filter, approximately that of low-cruise power. The icing conditions were so varied that the liquid-water-content range was 0.75 to 1.10 grams per cubic meter and the drop-size range was 12 to 30 microns.

Reduction in air flow caused by ice formations on the filters was used as a basis of comparison for the two configurations.

RESULTS AND DISCUSSION

Float-Type Carburetor

The limits of visible icing and serious icing at various float-type carburetor-air temperatures and humidity ratios for high-cruise, low-cruise, and glide power conditions are shown in figure 5. These data demonstrate the critical effect of throttle opening on icing in the carburetor by the increase in the visible- and serious-icing ranges as the power (and throttle angle) is decreased. At high-cruise power, the upper limit of visible icing occurs at a carburetor-air temperature of approximately 62° F, whereas at low-cruise and glide powers the upper limits occur at approximately 70° and 93° F, respectively. (Visible icing at glide power is designated serious.) For high-cruise, low-cruise, and glide power conditions, the upper limits of air temperature for serious icing are 62°, 63°, and 93° F, and the lower limits of relative humidity are 80, 60, and 30 percent, respectively.

The maximum temperatures at which serious icing was encountered for low-cruise and glide powers occurred at relative humidities less than 100 percent. Further increase in the moisture content at the maximum icing temperature added sufficient heat to the air to reduce the icing limits, as shown by the constant-enthalpy lines in figures 5(b) and 5(c). Figure 5(c) shows that the reduction in the icing limit at high humidity nearly parallels the lines of constant enthalpy. Because the total amount of moisture in the air is small at low temperatures during glide power, the quantity of ice formed may have been so slight that it escaped observation, which accounts for the increased relative humidity at the icing limits for these conditions.

No free water was injected into the charge air for the carburetor-manifold investigation because the presence of the filter, the plenum chamber behind the filter, and the updraft carburetor tends to eliminate free water from the air before it enters the carburetor.

In an icing condition with the usual float-type carburetor, ice formation over the idle discharge holes is a serious possibility, either at a cruise power or after the glide approach for a landing has been started. If, at cruise power, the idle discharge holes are blocked by ice and the throttle is then closed, the high-speed fuel system becomes inoperative because of low air flow in the venturi, and the engine receives no fuel from either system. Without warning, this icing can suddenly stop engine operation. During the glide approach, icing of the idle discharge holes has the same effect. Restarting the engine in the air is difficult, if at all possible, in many airplanes.

Another serious result of an icing condition is the accumulation of a considerable quantity of ice in the manifold at cruise power and additional ice accumulation during a glide, with resultant blocking to such an extent that high power cannot be regained.

The inherent design of float-type carburetors is such that the throttle is downstream of the fuel nozzles and the fuel must therefore pass around the throttle plate. Fuel evaporation with the accompanying cooling of the air originates at the fuel-discharge nozzles and continues downstream past the throttle plate and through the rest of the induction system.

Furthermore, expansion of the air in the venturi upstream of the throttle and at the restriction of the throttle gives an additional cooling effect. In an atmosphere with high moisture content, condensation may take place in the venturi with additional condensation and freezing caused by expansion of the air past the throttle and the refrigeration effect of fuel evaporation. In 1 hour, at a temperature of 42° F and with a relative humidity of 100 percent, the throttle was opened from the low-cruise-power setting to wide-open throttle, a change of approximately 50° in throttle-plate angle, in an attempt to maintain the original air flow as ice formed in the system. In another 8 minutes, the air flow became very erratic and the fuel-air ratio decreased to 0.045, which is below the operating limit.

Observed locations of ice formation at glide-power conditions are shown in the sectional view of the carburetor and the manifold of figure 2. The throttle and the throttle body downstream of the throttle are most susceptible to ice formation and in the range of serious icing conditions ice was occasionally observed to build down from the top of the manifold and out from the walls of the manifold riser in sufficient quantities to block the riser passage completely.

In the float-type carburetor, the fuel must pass around the throttle plate at all times and differentiation between icing caused by expansion cooling of the air passing through the carburetor and evaporative cooling caused by the fuel is impossible. No separate extensive investigation of throttling icing was made. One check point made without fuel flowing, however, showed that even at a temperature near freezing, with high relative humidity, throttling ice (or frost) was barely visible and was considered negligible.

A limited investigation made with a jacketed throttle body, a heated hollow throttle plate, and a jacketed manifold, with warm water as a heating medium showed that for complete icing protection

of the critical parts a maximum heat input of approximately 2000 Btu per hour was required. This condition occurred at high-cruise power with a carburetor-air temperature of 35° F, which was approximately the low temperature limit of the serious-icing range. The throttle plate required approximately 800 Btu per hour and the remaining heat was divided approximately equally between the throttle body and the manifold.

In flight, engine lubricating oil may be used as a heating medium, but has disadvantages in the hazards resulting from complication of the oil system and congealing of the oil, especially when the throttle is to be heated.

Another source of heat available for ice protection is the engine exhaust. A consideration of the practicability of passing exhaust gas through a hollow throttle plate for ice protection indicates that sufficient heat might be made available in a suitably insulated system. If the heat requirements of the throttle are based on that obtained with water as a heating medium, and an available exhaust-gas temperature of 600° to 700° F is assumed, an exhaust-gas flow of 8 pounds per hour with a temperature drop across the throttle of approximately 400° F would be required at high-cruise power.

A brief calculation indicates that supplying the required amount of exhaust gas to the throttle under glide-power conditions would be more critical than at high-cruise power because the exhaust-gas flow, pressure, and temperature are at reduced values. The normal exhaust-gas pressure is near the ambient-air pressure and the exhaust-gas temperature may be as low as 300° F at the glide-power condition. A provision for increasing the exhaust back pressure or reducing the pressure at the jacket outlet would be necessary to induce the required flow through the jacket.

Pressure-Type Carburetor with Unheated Manifold

The icing limits for the pressure-type carburetor are shown in figure 6. Only low-cruise and glide power conditions were investigated for this carburetor because critical icing occurred only at the smaller throttle openings. Visible icing was found to occur over a wide range of temperature and humidity. The upper limit of visible ice was 79° F at low-cruise power and 87° F at glide power, with a lower limit of relative humidity at approximately 33 percent for low cruise and approximately 15 percent for glide power. Serious icing was much less extensive for low-cruise power than for glide

power and was confined to a temperature range from 48° to 55° F, with relative humidities from 90 to 100 percent. The limits of serious icing at glide power are seen in figure 6(b) to be approximately 75° F and 32-percent relative humidity. The fuel nozzle in the pressure-type carburetor is located downstream of the throttle. The increase in the range of conditions at which serious ice may form when the throttle is more nearly closed (glide power) is caused by eddying of the fuel spray from the discharge nozzle back to the throttle plate (fig. 3), which results in greatly increased cooling effect by fuel evaporation in the region between the discharge nozzle and the throttle plate.

At low-cruise power, icing of the system was confined almost entirely to the top or ceiling of the manifold directly above the riser from the carburetor. Very little eddying of the fuel spray occurred and, as a result, no ice formed on the throttle. At glide power, the manifold icing was similar to that encountered at cruise power, but heavy frost and ice formed on both the top and the bottom and on the edges of the throttle plate. Slight icing on the fuel-discharge nozzle was occasionally visible at glide power, but was not found to be serious.

Several instances of extremely rich fuel-air ratios resulted at glide power in the serious-icing range and the air flow was reduced one-third or more. This effect was due to the fact that in the idle-speed range the fuel flow is controlled by the position of the idle needle valve, which in turn is mechanically operated by a linkage to the throttle. The fuel flow is therefore a function of throttle position and remains constant while the air flow is reduced by ice formation on the throttle, which results in a rich mixture.

Throttle icing, which is caused by cooling of the air during expansion through the throttle restriction, occurred over a very limited range. For throttle ice to occur in saturated air, the amount of cooling by expansion must be sufficient to condense the moisture and reduce the air temperature below the freezing level. In the case of unsaturated air, additional cooling is required to lower the air and moisture temperature to the dew point. A small amount of throttle ice was observed in the pressure carburetor at glide power with the fuel shut off and when saturated air was used at 33° F. At a slightly lower humidity, however, no ice could be detected.

Pressure-Type Carburetor with Oil-Jacketed Manifold

Experiments with the oil-jacketed manifold indicated elimination of all significant ice formations in the manifold. Under conditions found to be serious with no heating, only light icing occurred, which was well within the acceptable tolerance for manifold icing. No visible icing occurred in the manifold at air temperatures above 60° F and serious icing at low-cruise power was completely eliminated. Manifold icing was reduced at glide power, but fuel-evaporation icing at the throttle remained serious and was more significant.

Air-Scoop and Filter Icing

The results of an effort to eliminate impact icing on light-airplane air scoops and filters by means of a design to induce inertia separation of the water droplets from the intake air are shown in figure 7 for two air-scoop and filter combinations. The time required to cause an air-flow reduction of 25 percent by the formation of ice on the filter for tunnel-air temperatures from 17° to 22° F is used as a basis of comparison of the two systems in the following table:

Icing condition			Time for 25-percent reduction in air flow (min)	
Rating	Liquid-water content (grams/cu m)	Mean effective droplet diameter (microns)	Standard air scoop	Modified air scoop
Light	0.75	12-15	4	12
Medium	.95	17-20	12	16
Heavy	1.10	27-30	14	25

The modified air scoop effected inertia separation of only the larger water droplets from the charge air, as evidenced by deposits of frost-like ice formations on the filter while heavier ice formations were being deposited on the exposed parts of the air scoop. As shown in the foregoing table, the modified air scoop allowed additional tolerance in time before the predetermined limit of air-flow reduction was reached. Inertia-separation systems for complete ice protection of light-airplane inlets were

found to be impractical, however, because of the prevalent low inlet velocities. Results of another water-inertia-separation investigation (reference 2) indicate that even with relatively high velocity air, small droplets in the order of 10 microns in diameter prove to be very difficult to remove completely.

Icing to the extent shown on the photographs in figure 7 is not likely to be encountered in light-airplane operation, but is presented as a basis of comparison of the icing characteristics of the two air-scoop configurations. The time for 25-percent reduction in air flow in the preceding table shows that more rapid blocking of the filter took place under the lighter icing conditions because a greater percentage of small droplets was present. Observation of the filters after icing revealed that at the medium and heavy icing conditions, direct impingement and freezing of the water droplets on the ridges and valleys of the filter (cross-sectional view of filter in fig. 4) was primarily responsible for the air-flow reduction, whereas in the light-icing condition the small water droplets were carried with the air stream to all surfaces of the filter and caused more effective blockage.

Experience indicates that most current induction systems with an alternate supply of heated unfiltered air will allow flight in impact-icing conditions so long as other parts of the airplane can endure icing, if proper judgment is exercised by the pilot in operating the heated-air system.

General Observations

Float-type carburetors, by virtue of their design and operation, are inherently more susceptible to icing at the throttle than pressure-type carburetors.

Current induction systems that use exhaust-heated alternate-air supplies for ice prevention suffer loss in power from the reduction in charge-air weight flow, but are generally adequate when the carburetor heat is turned on before serious icing occurs.

Proper jacketing and heating of all parts exposed to the fuel spray can satisfactorily reduce or eliminate icing in the manifold and in the float-type carburetor. Jacketing of the manifold is relatively simple, but jacketing of the carburetor, including the throttle, requires relatively complicated design.

Pressure-type carburetors, fuel-injection systems, or any other method of metering and injecting fuel into the air stream at a point sufficiently remote from throttles or other protuberances and in a relatively warm location seem to be a satisfactory solution to the refrigeration icing problem. The location of fuel nozzles, either in the carburetor or in close proximity to the throttle, where eddying fuel can strike unprotected parts, is unsatisfactory for an ice-free design.

Proper jacketing and heating of the vertical riser of the manifold and the manifold distributor section, including the top and short sections of the outlets to the individual cylinders, will eliminate the formation of ice in the critical parts of the manifold for the pressure-type carburetor.

A simple inertia-separation system will not satisfactorily eliminate impact icing on inlet filters because of the low air velocities. A sheltered air inlet taking alternate air from the engine compartment will provide satisfactory protection from impact icing on the filter. Because light-airplane intake systems produce very little ram pressure, the loss in engine power resulting from such a change would be insignificant.

SUMMARY OF RESULTS

From an investigation of the icing characteristics of light-airplane engine induction systems conducted on laboratory installations of carburetors and manifolds, air scoops, and filters, the following results were obtained:

Float-Type Carburetor

1. Serious icing occurred up to carburetor-air temperatures of 62°, 63°, and 93° F and the lower limits of relative humidity were 80, 60, and 30 percent, for high-cruise, low-cruise and glide power conditions, respectively.

2. The carburetor was susceptible to icing at the throttle plate and on the throttle body around the idle discharge holes, and the manifold iced primarily in the vertical riser.

3. The formation of heavy ice in the carburetor and manifold resulted in air-flow reduction, which could not be regained by opening the throttle to the wide-open position.

4. A jacketed manifold and throttle body and a heated throttle plate provided complete anti-icing protection at high-cruise power with saturated carburetor air at 35° F, using a heating medium that supplied approximately 2000 Btu per hour, of which approximately 800 Btu per hour were required for the throttle plate and the balance was approximately equally divided between the throttle body and the manifold.

Pressure-Type Carburetor

1. Serious icing occurred between carburetor-air temperatures of 48° and 55° F with relative humidities from 90 to 100 percent at low-cruise power and up to approximately 75° F with relative humidities greater than 32 percent at glide power. No serious icing occurred at the high-cruise power condition.

2. The throttle plate was completely free of ice at low-cruise power, but eddying of the fuel spray caused serious icing of the throttle plate at glide power with several instances of extremely rich fuel-air ratios occurring because fuel metering in the idle range is governed by throttle position rather than air flow.

3. Throttling icing with carburetor air at or below saturation was negligible.

4. The oil-jacketed manifold with an oil flow and inlet temperature typical of operating conditions prevented serious icing at low-cruise power and confined visible manifold icing to carburetor-air temperatures below 60° F. At glide power the heated manifold did not prevent serious icing of the throttle plate.

Air-Scoop and Filter Icing

1. Inertia separation of water droplets in the order of 10 microns in diameter from the inlet-air stream appeared to be impractical for light-airplane induction systems because of the low air velocities.

2. For both the standard and modified air scoops, icing conditions in which a large percentage of small droplets existed caused more rapid blocking of the filter than icing conditions in which large droplets were predominate.

Lewis Flight Propulsion Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, October 6, 1948.

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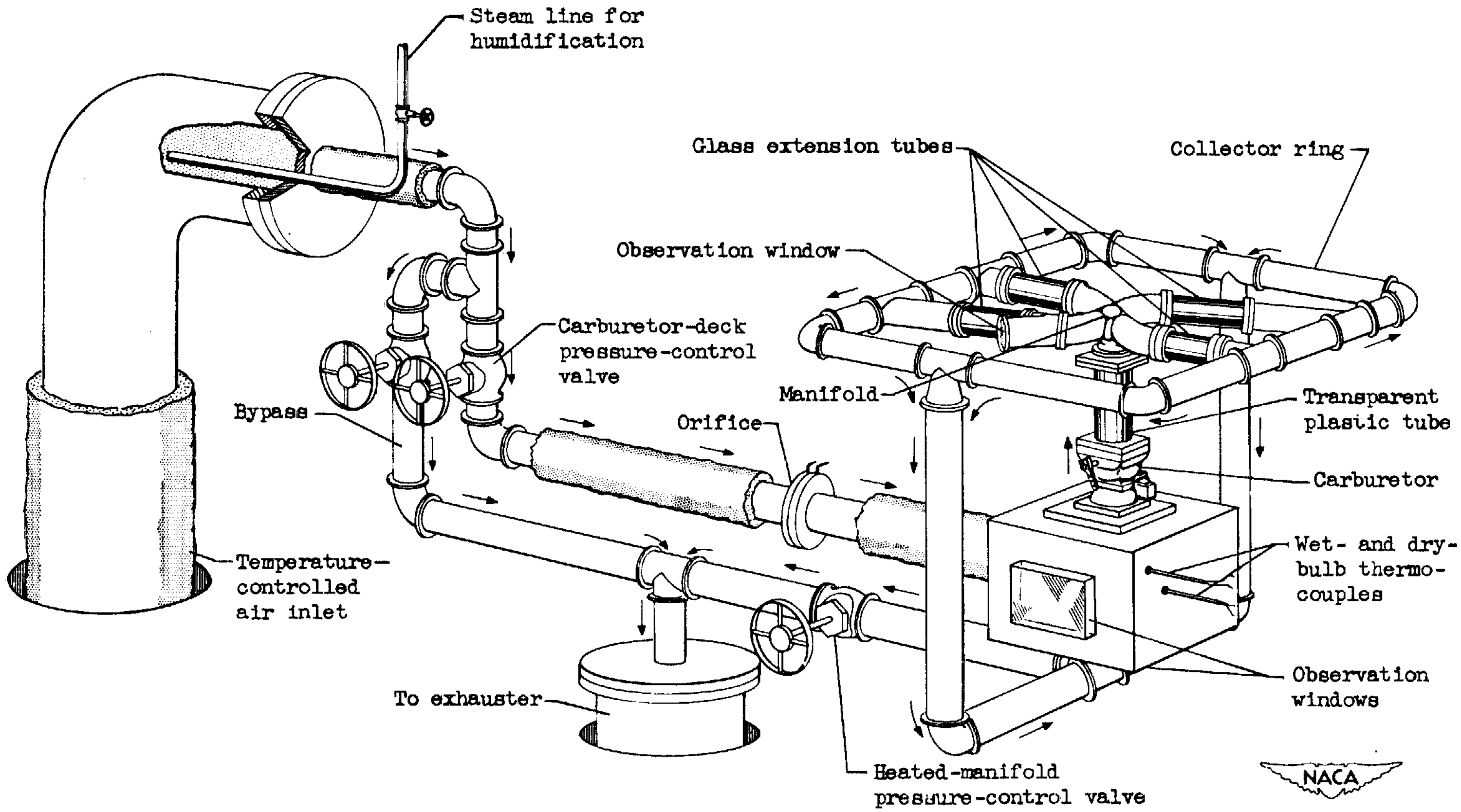


Figure 1. - Schematic diagram of apparatus for light-airplane-engine induction-system-icing investigation.

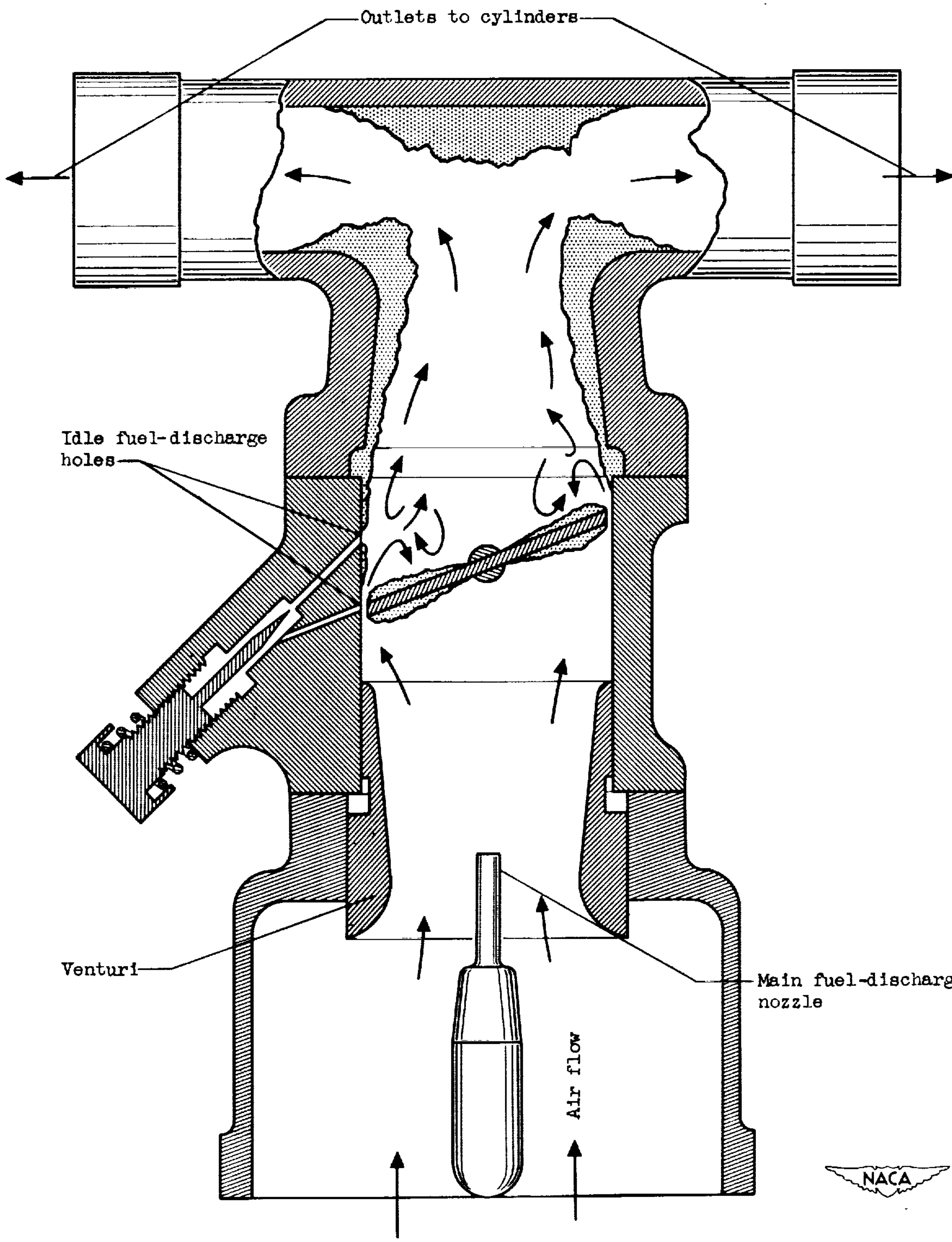
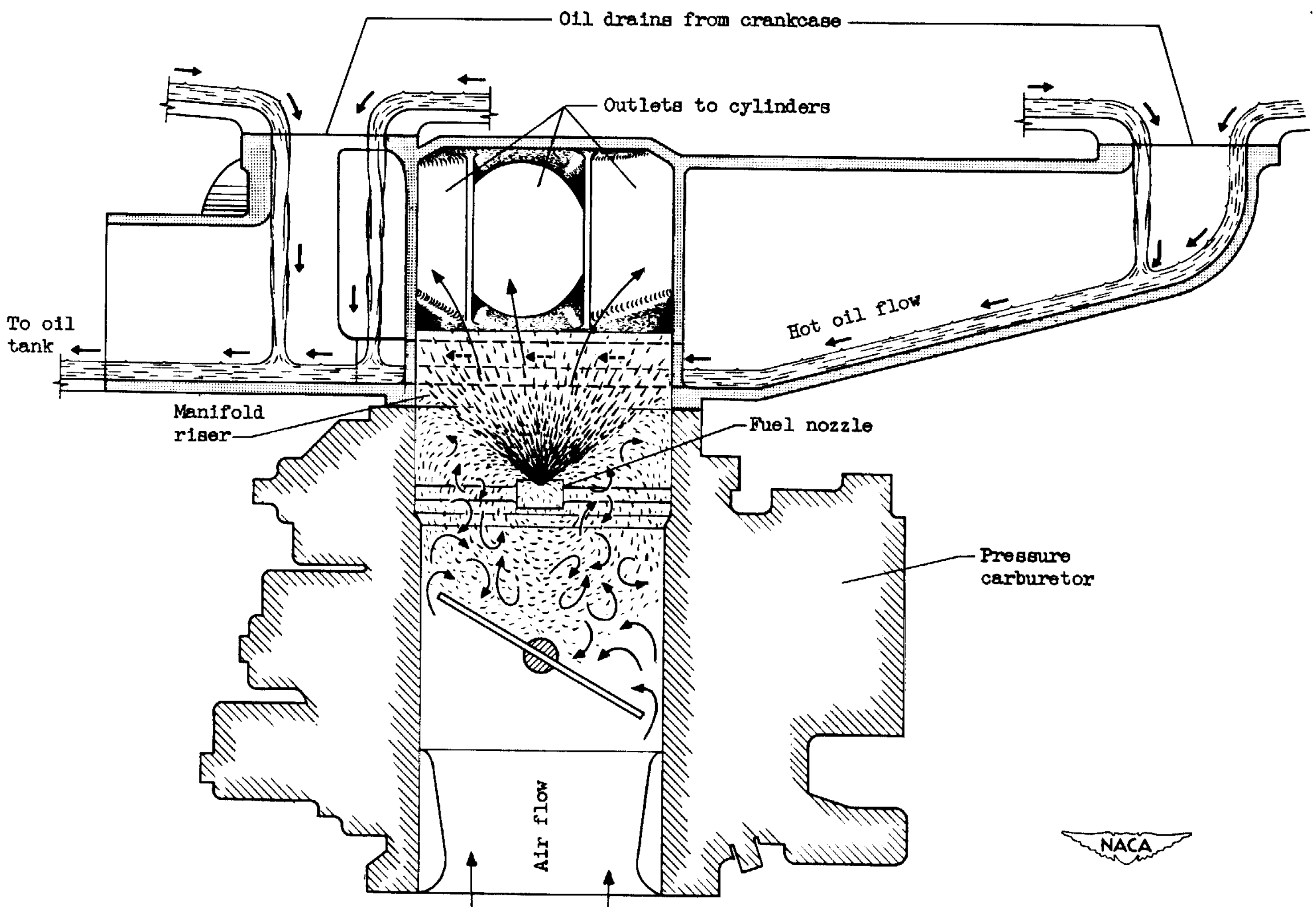
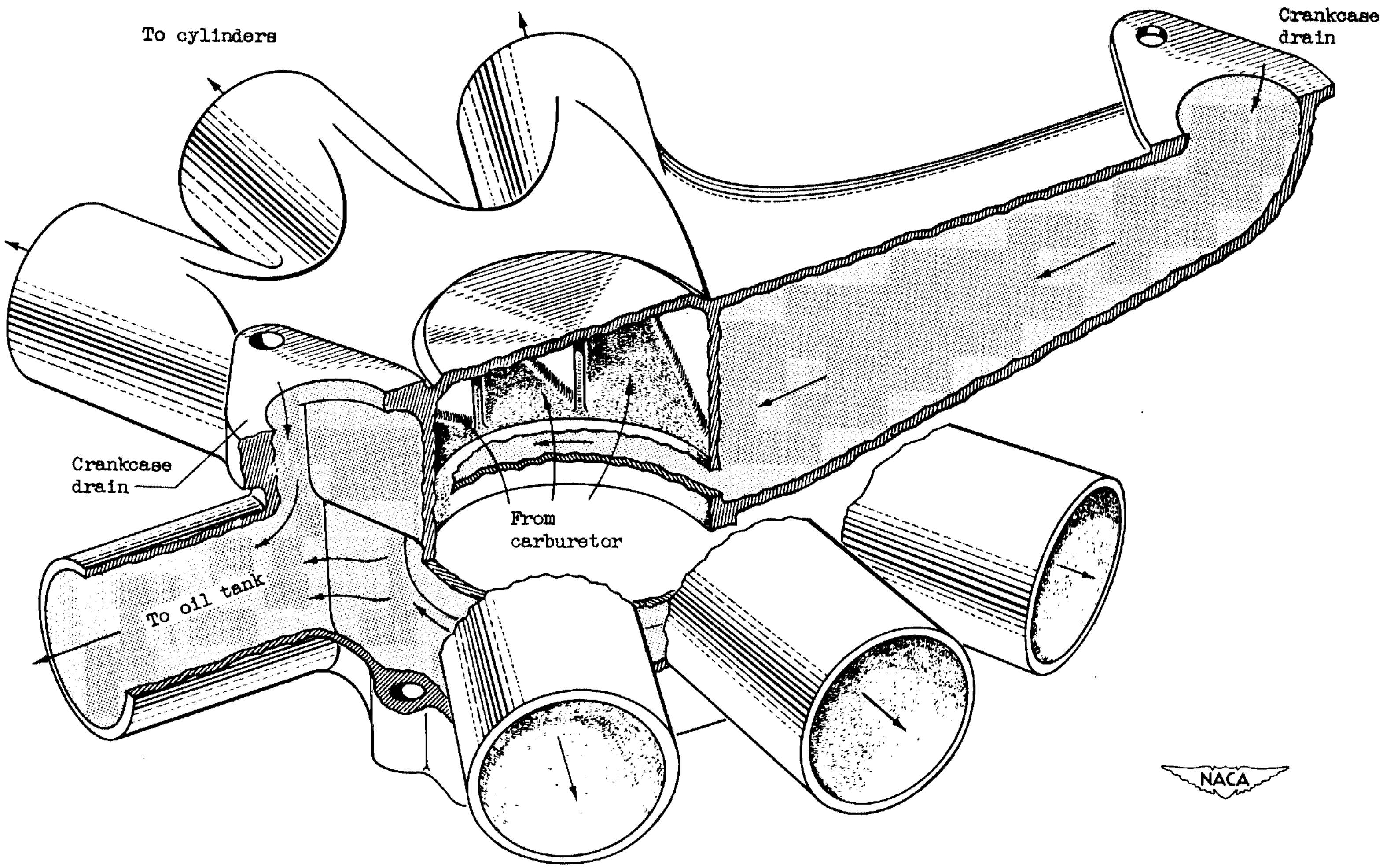


Figure 2. - Schematic diagram of float-type carburetor and manifold showing typical ice formation at glide-power throttle setting.



(a) Schematic diagram of carburetor and manifold showing eddying of fuel spray at glide-power throttle position.

Figure 3. - Pressure-type carburetor and oil-jacketed manifold.



(b) Sectional view of manifold showing oil and mixture passages.

Figure 3. - Concluded. Pressure-type carburetor and oil-jacketed manifold.

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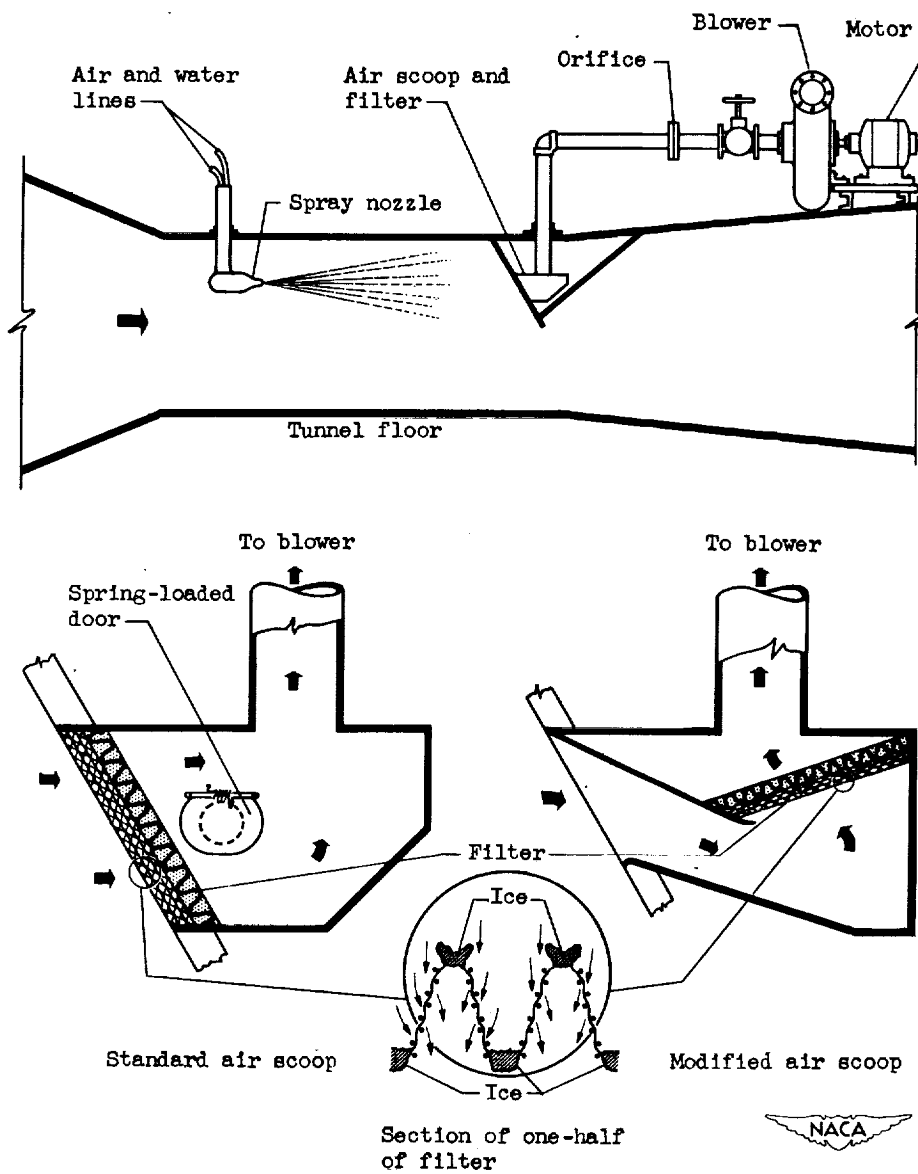

Figure 4. - Schematic diagram of apparatus used for filter and air-scoop impact-icing investigation in icing research tunnel.

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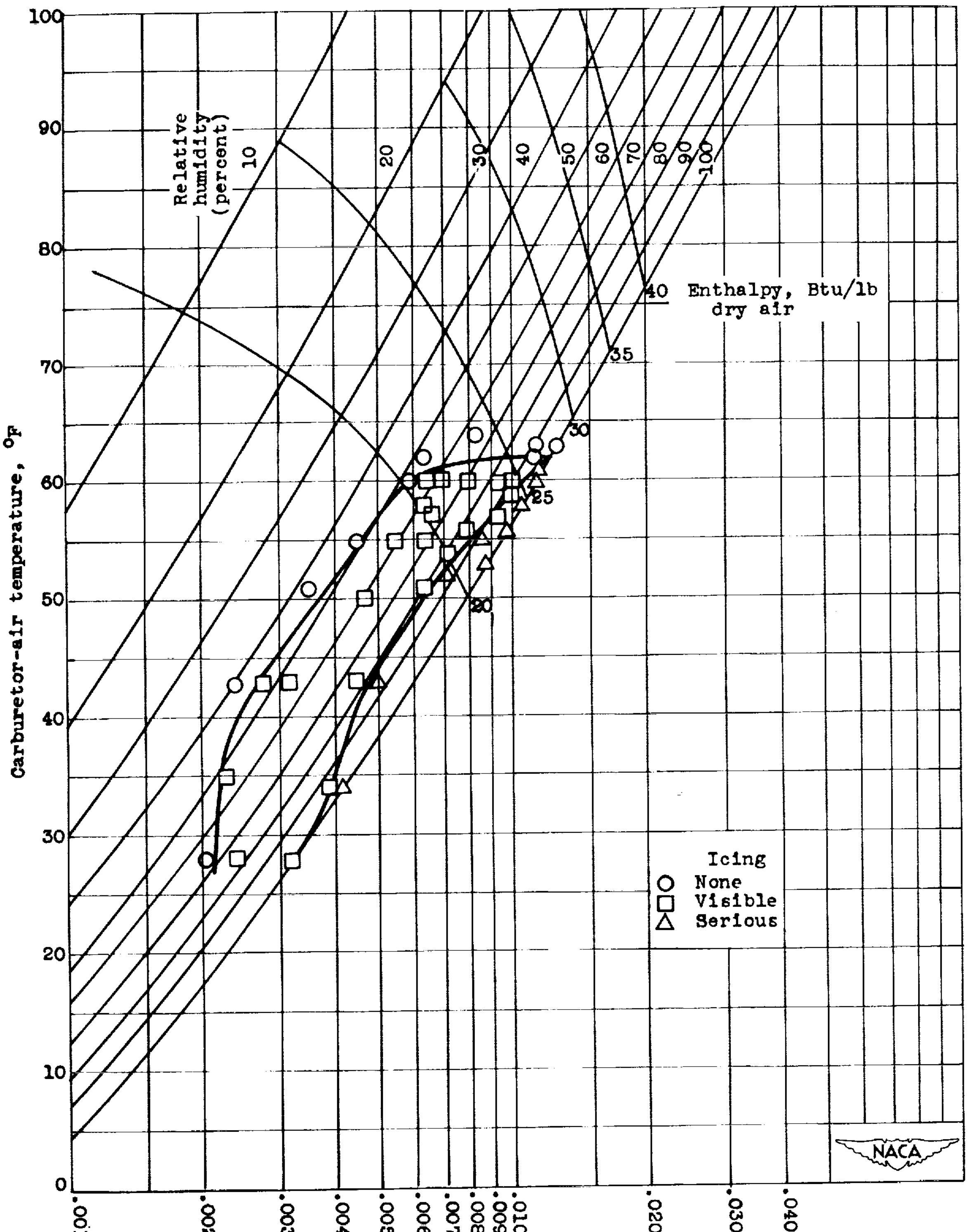

(a) High-cruise power.

Figure 5. - Icing limit for float-type carburetor.

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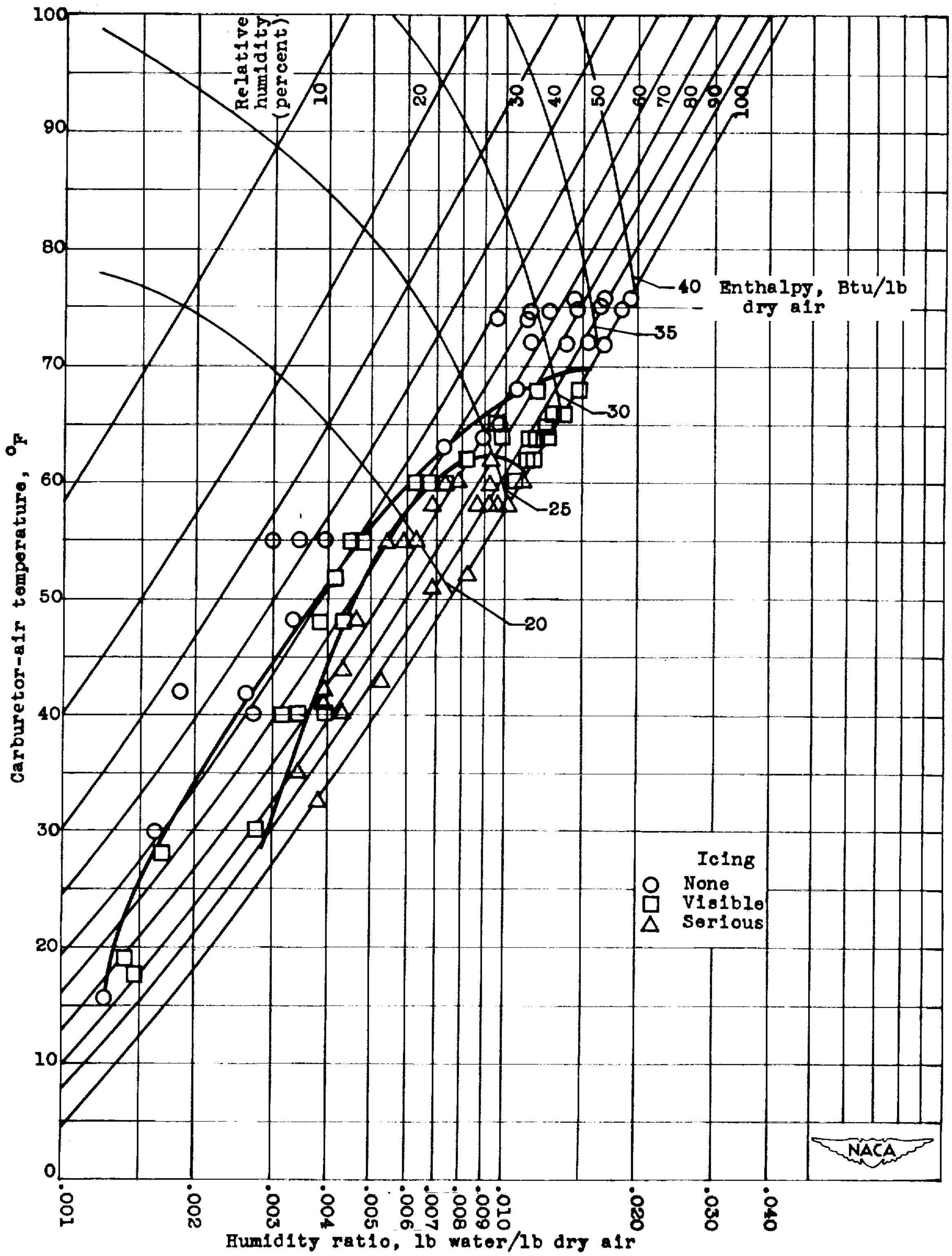
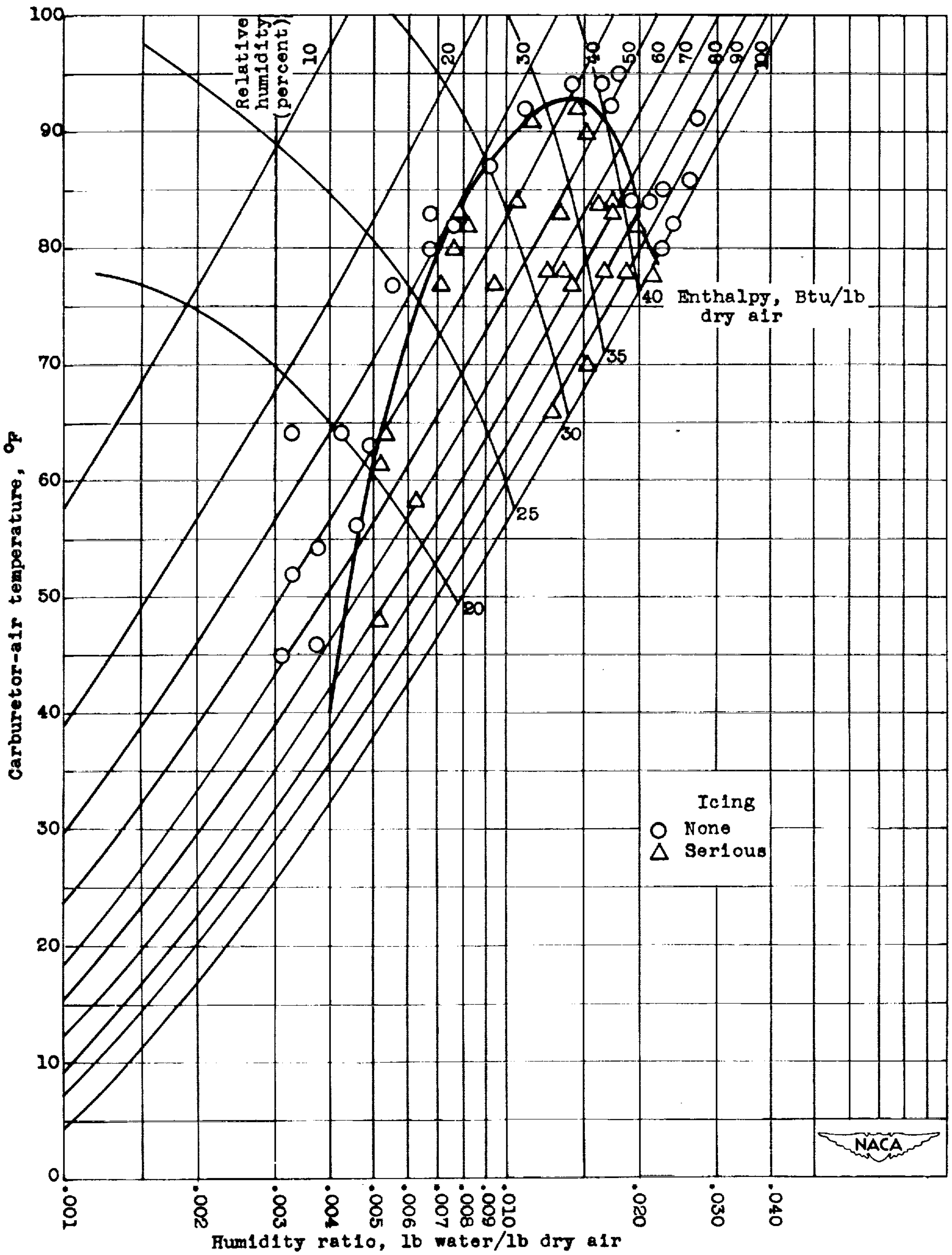


(b) Low-cruise power.

Figure 5. - Continued. Icing limit for float-type carburetor.



(c) Glide power.

Figure 5. - Concluded. Icing limit for float-type carburetor.

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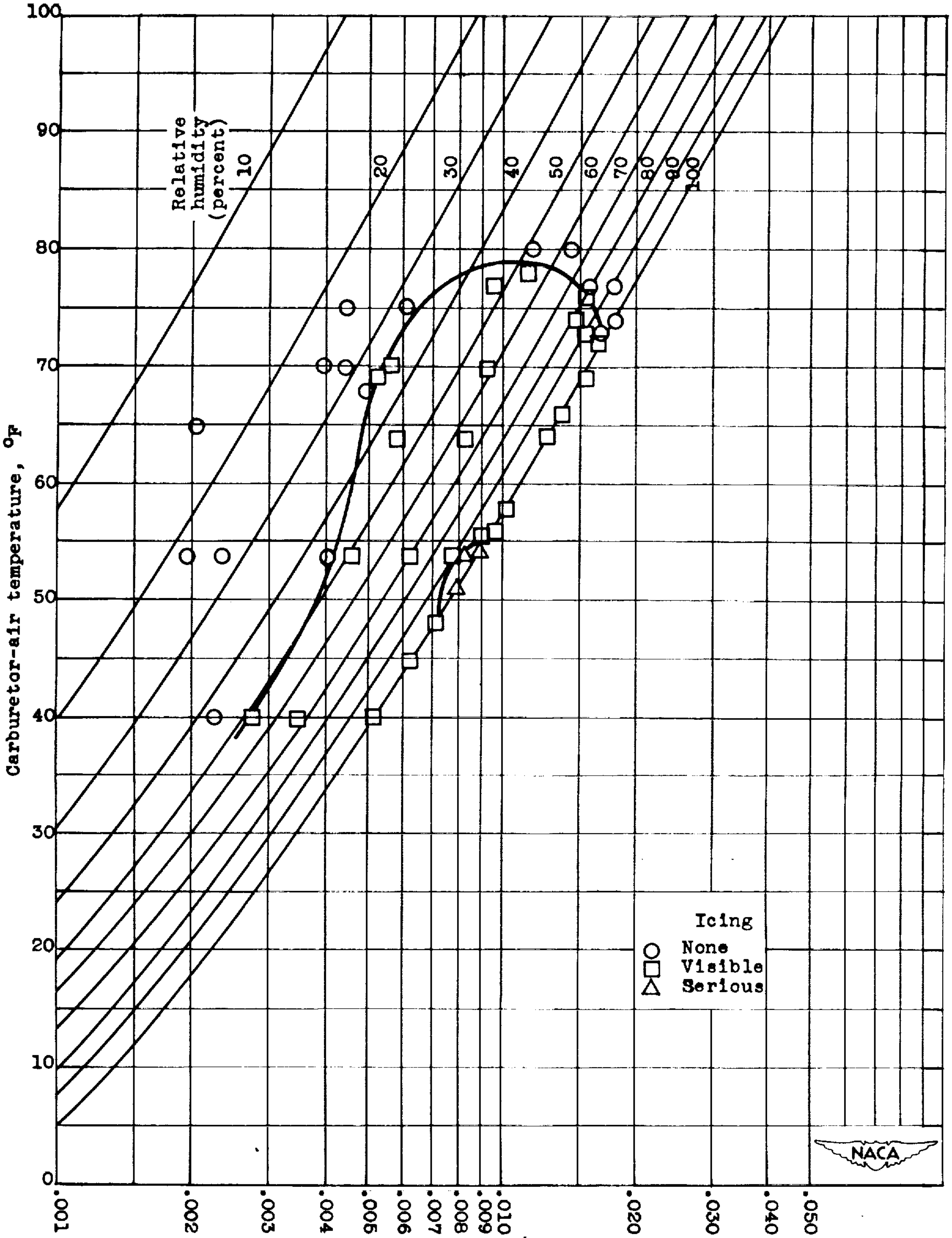
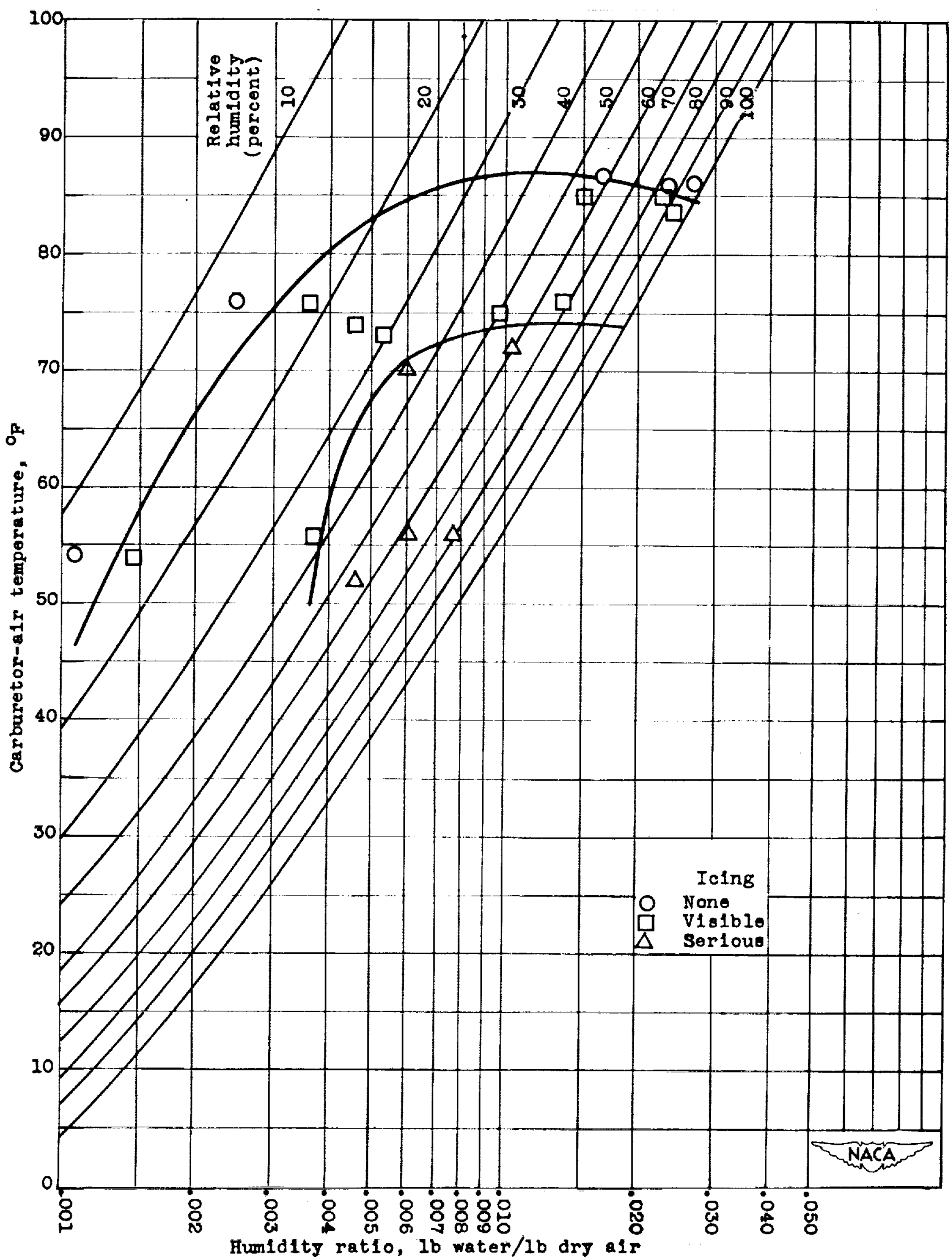


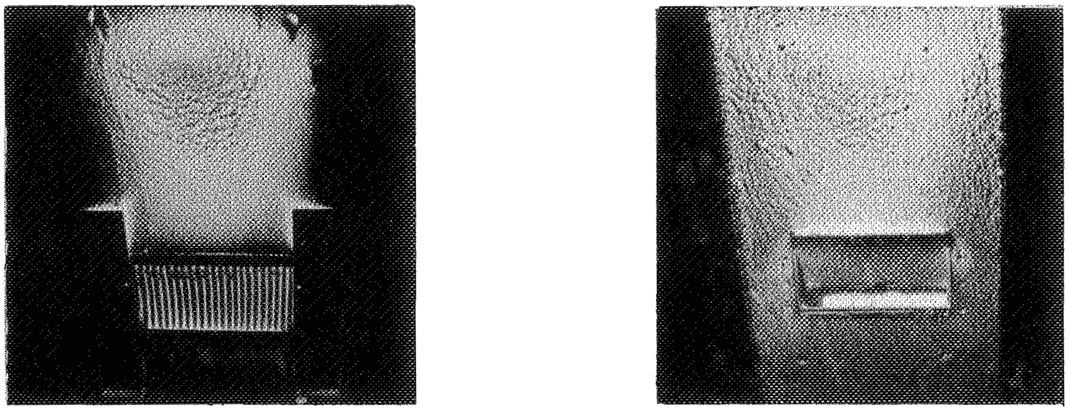
(a) Low-cruise power.

Figure 6. - Icing limits for pressure-type carburetor.

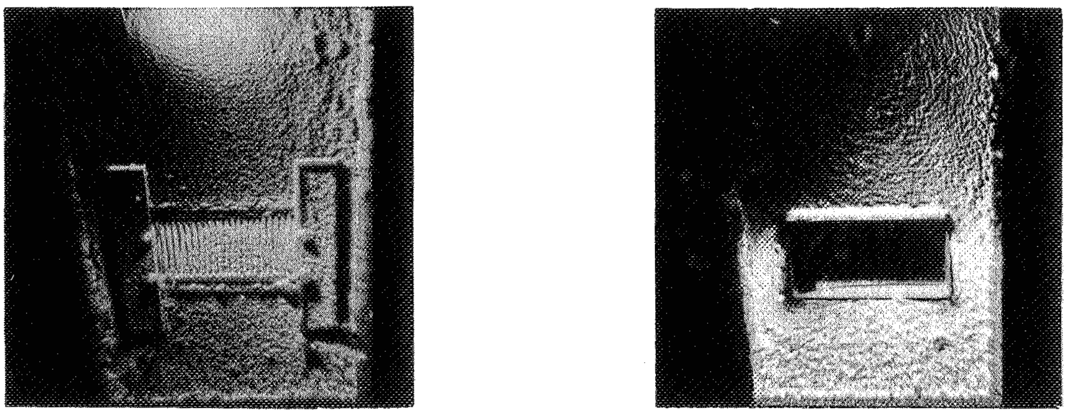


(b) Glide power.

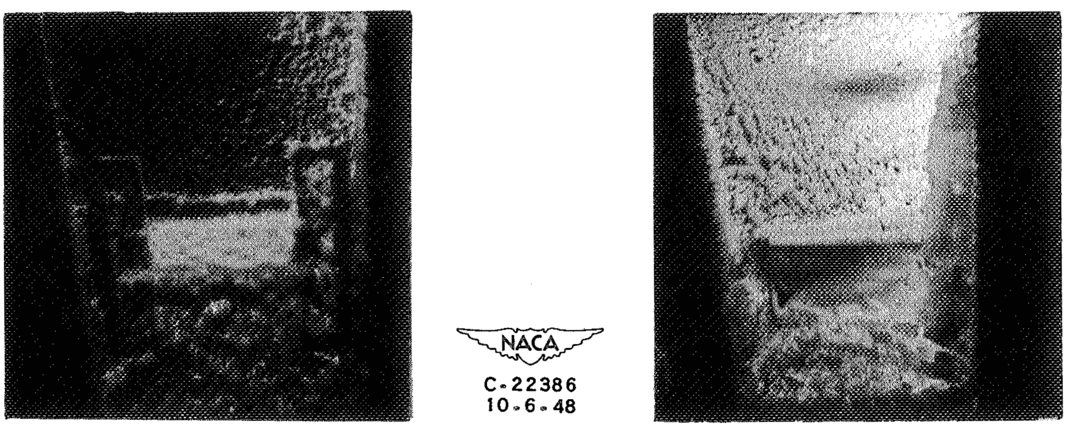
Figure 6. - Concluded. Icing limits for pressure-type carburetor.



Standard air scoop Modified air scoop
(a) Light-icing conditions.



Standard air scoop Modified air scoop
(b) Medium-icing conditions.



Standard air scoop Modified air scoop
(c) Heavy-icing conditions.

Figure 7. - Ice formations on standard and modified carburetor-air inlets for three simulated-icing conditions. Tunnel-air temperature, 17° to 22° F; air velocity, 80 miles per hour.